MDPI Film Processing

Harder, Better, Faster, Stronger

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Digital Library Brown Bag Series #dlbb

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Definitions (in no particular order)

- 1 Petabyte = 1,000 Terabytes = 1,000,000 Gigabytes = 10^{15} bytes
- Scholarly Data Archive (SDA) – IU's tape-based storage system
- High Performance Storage System (HPSS) – The software under SDA
- Transcode – Convert from one format to another (.wav -> .mp3)
- Package or Object – All of the digital files for a single physical object
- Master – A file made from the digital physical media
- Derivative – A file created by transcoding another (i.e. thumbnail)
- Tarball – A file made with the tar utility which combines multiple files into one (similar to a zip file, but with no compression)
- "Me", "I", "We" – May refer to the software and not me personally

A petabyte is equal 15,625 64G USB flash drives

A view inside the SDA tape library

Core of HAL 9000

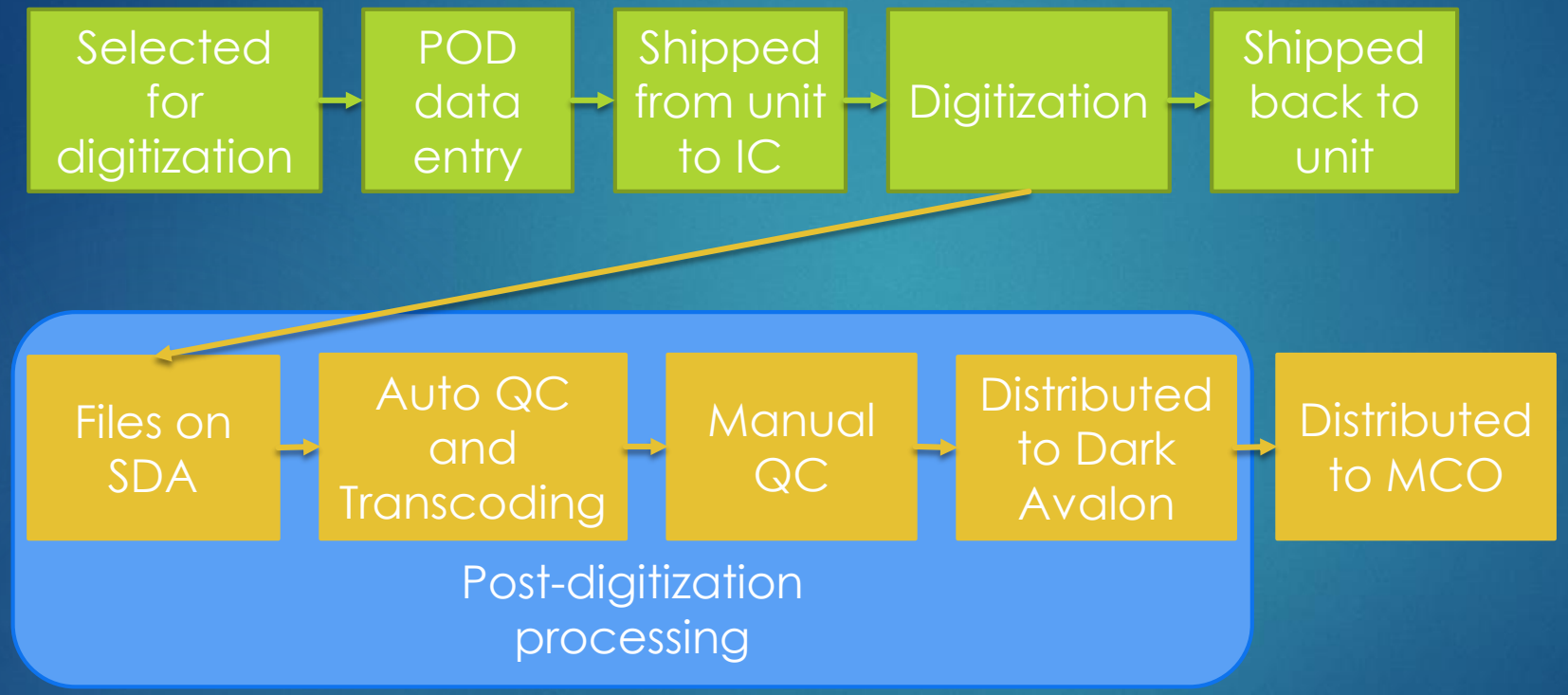
MDPI review

- Media Digitization and Preservation Initiative
- Announced October 2013 by President McRobbie
  - Digitize and preserve rare and unique time-based media in the university collections by 2020
  - Around ~~280,000~~ **325,000** A/V items identified for digitization
  - Film designated as Phase II
- Partnership with Memnon Archiving Services (a division of Sony)
  - Memnon will digitize the bulk of the content
  - IU Digitization Studios will handle rare, unique, or fragile objects

MDPI timeline

- 2013
  - October: Project announcement by President McRobbie
- 2015
  - June: First production audio batches processed successfully
  - November: First production video batches processed successfully
- 2016
  - February: Objects delivered to “Dark” Avalon for collection managers
  - Second half: Investigation into Phase II (Film) began
- 2017
  - November: First production film batches processed successfully

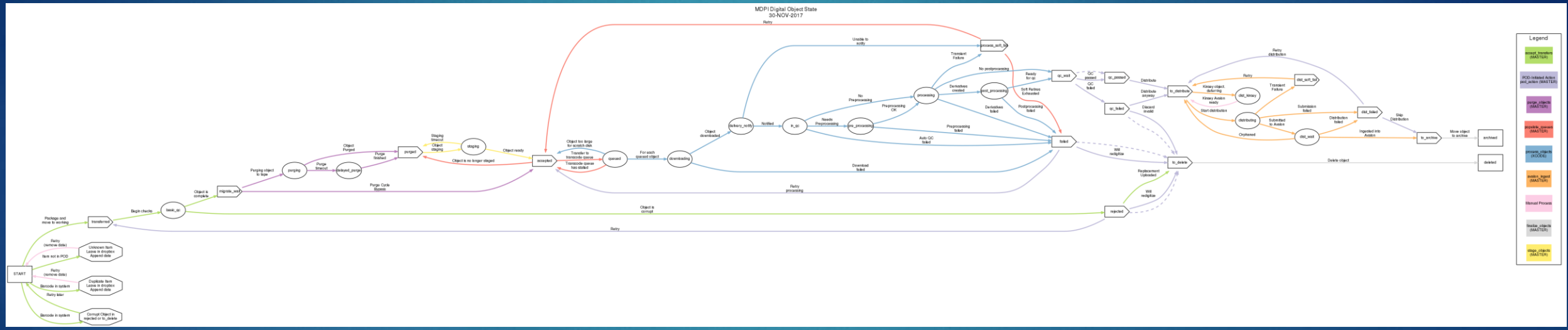
MDPI object overall workflow



Physical Object

Digital Object

Post-digitization processing (A/V and Film use same workflow)



Post-digitization processing summary

- Each digital object must be…
  - Verified
    - Valid barcode? Correct files from digitizer? Stored correctly on tape?
  - Processed
    - Auto QC'd. Derivatives created. Metadata gathered
  - Quality Checked by Humans
    - Subjective issues (color, sound , etc)
  - Distributed
    - All 'passed' objects are sent to a "Dark" Avalon for collection managers
    - Will distribute to external users at some point in the future

A/V & Film processing requirements

A/V

- ~300 hours of content per day
- >15 different digitization packages
- 10% human QC
- Digitization 5 days per week

Film

- 16 hours of content per day
- 1 digitization package format
- 100% human QC
- Digitization 6 days per week
- Higher quality derivatives

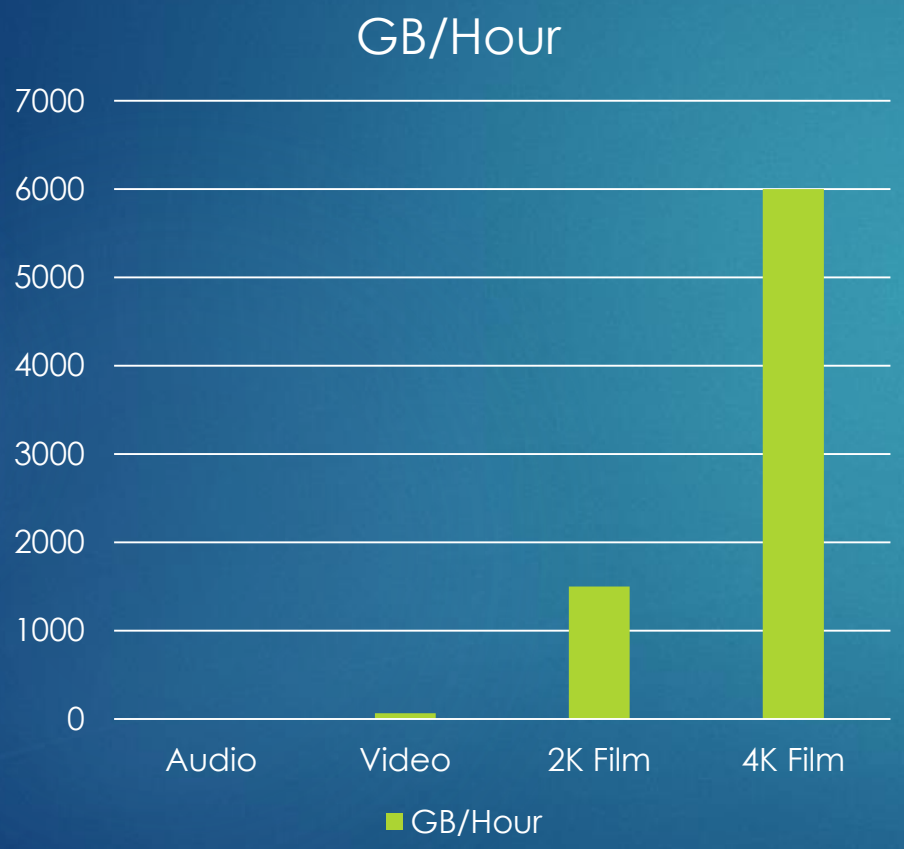
Film should be easy!

Harder, Better, Faster, Stronger

- Film is Harder than A/V
- The solution is to do things
  - Better – Re-organize existing solutions
  - Faster – Implement faster methods or solutions
  - Stronger – Throw hardware at the problem or make it more robust

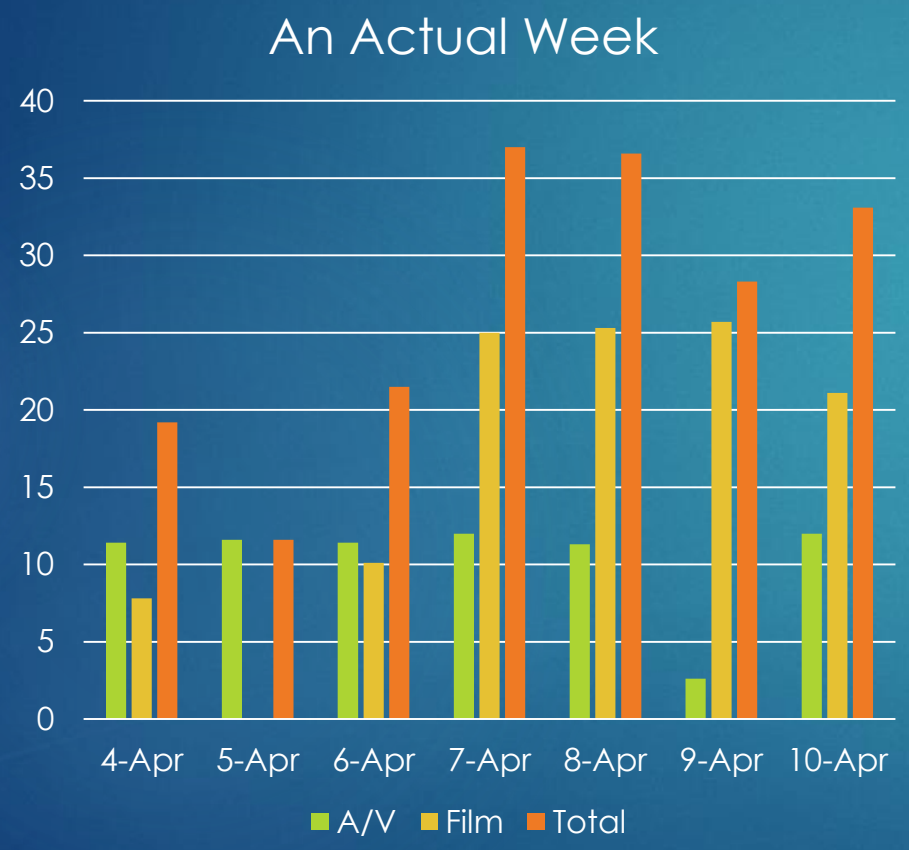
An hour of Film is huge…

Harder



- Archival sizes for 1 hour of…
  - Audio: 4G
  - NTSC Video: 64G
  - 2K Scanned Film: 1500G
  - 4K Scanned Film: 6000G

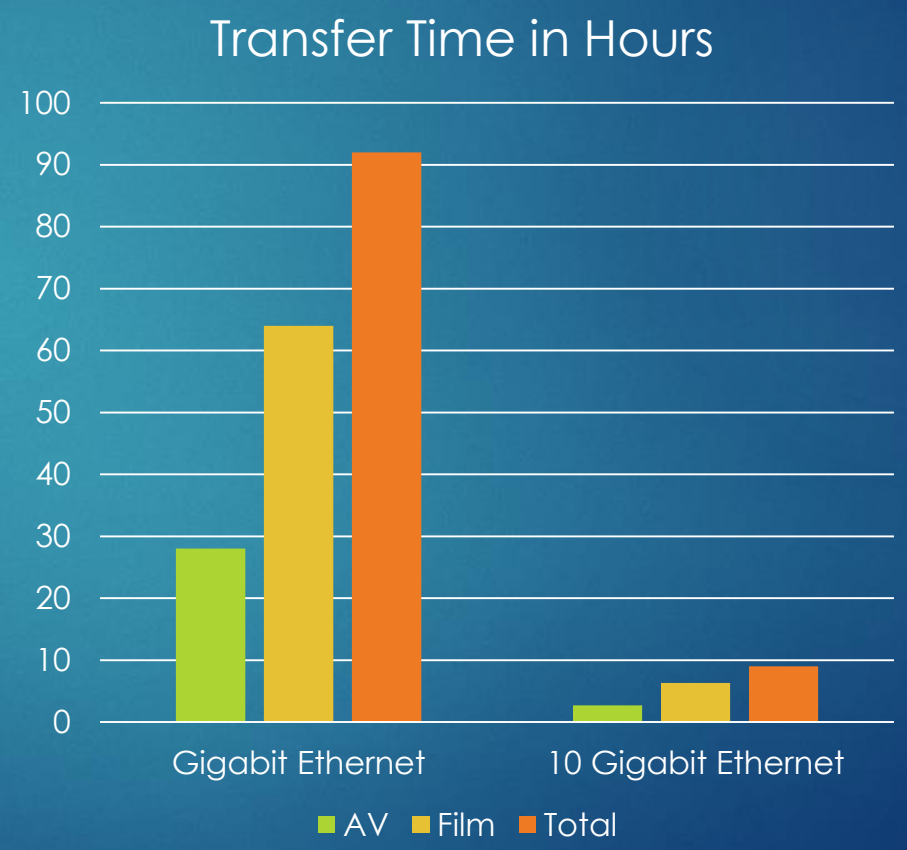
… so a day's transfer is also huge.



- 16 hours of film per day
  - 95% 2K Scan => 22.8T
  - 5% 4K Scan => 4.8T
  - 27.6T per day
- In addition to 8-12T for A/V

Which means it must be fast!

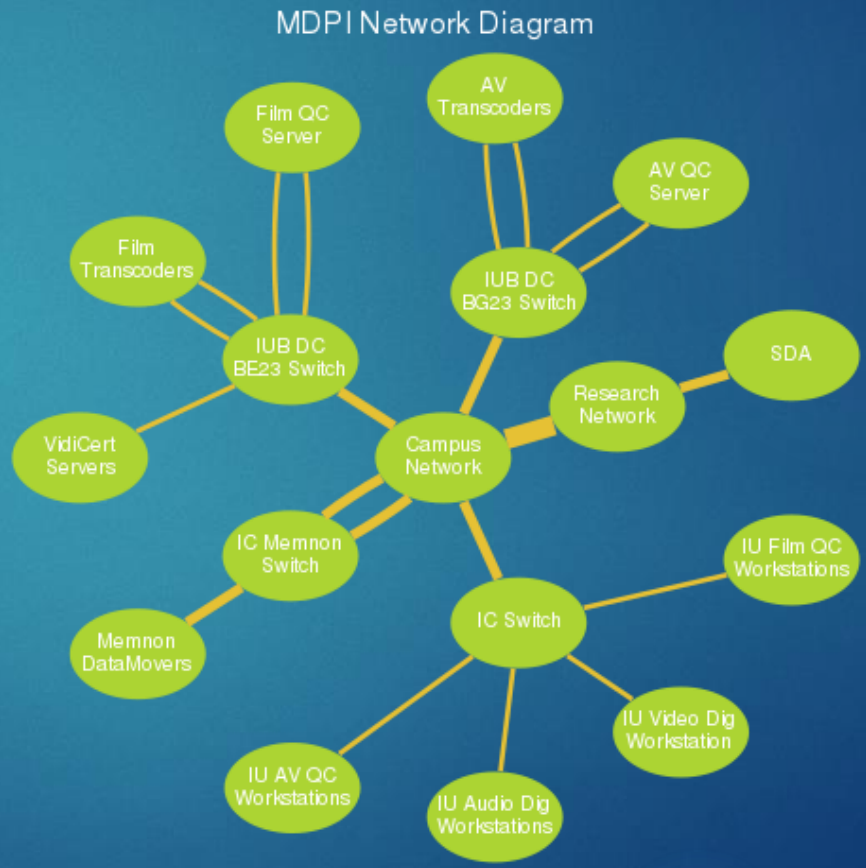
- There's only 24 hours per day to handle transfer, transcode, and storage of new content
- At theoretical peak, 10GbE will handle the rate handily
- BUT, theoretical peak is rarely achieved:
  - SDA transfer rates are closer to Gigabit Ethernet
  - Lots of idle time waiting for tape migration
  - Memnon doesn't hit peak for upload



Network upgrades for Film

Faster

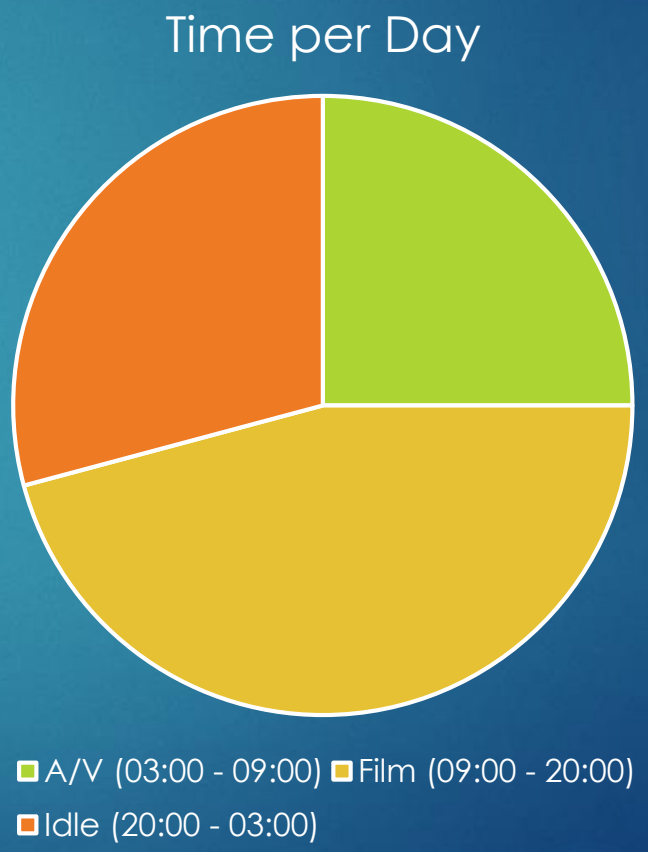
- Memnon added an additional 20Gbps uplink to Campus Network
- Film-related servers are in a different rack than AV
- A second SDA-only 10Gbps network link added to all Transcoders and QC machines
- Bottom line: IU Transcoders and QC machines can handle full speed transfers to/from SDA AND full speed transfers to/from workstations in the IC



Revise transfer windows

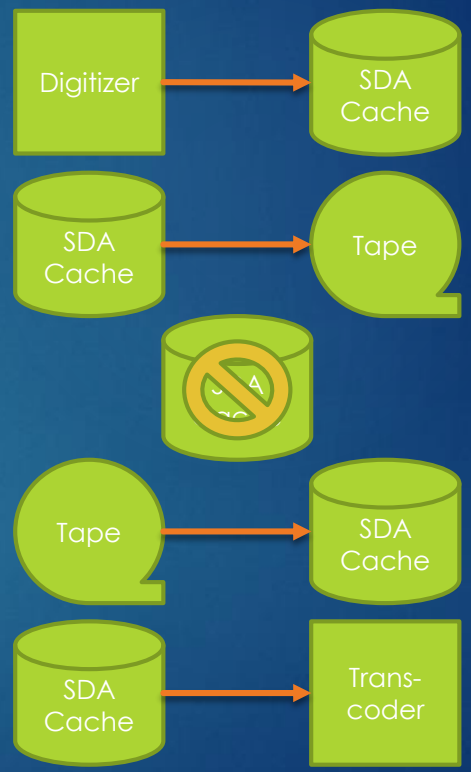
Better

- 3am to 9am is A/V transfers
- 9am to 8pm is Film transfers
- 8pm to 3am is idle/overflow
- 7 hours of room to grow
- Possible because
  - Improved network topology
  - Memnon transfer optimization

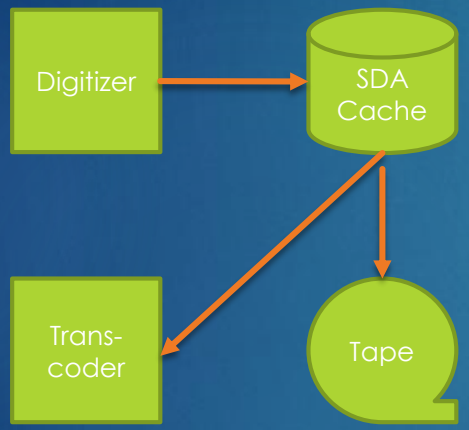


Tape validation data flow

- Current HPSS doesn't validate internal copies
  - Data corruption is possible!
- Normal flow
  - New objects are loaded into the SDA disk cache
  - Data is migrated from cache to tape
  - The SDA disk cache is purged
  - The data is staged from tape back into the disk cache
  - Data sent from cache to transcoders
- Time consuming
  - For A/V we can do this with 100% of the content
  - Film takes hours to write to tape, and hours to recall…



Reduced validation for Film



- Reduced validation
  - Wait for a tape copy to be made
  - Send the object from SDA cache to the transcoder
- Film objects ending with an even digit use this method
  - Can start transcoding hours earlier
  - Allows transcoders to keep up with daily uploads
- Compatible with HPSS's End-to-End Data Integrity
  - Enables validation on all data moves within HPSS
  - Coming with the SDA upgrade this Summer
  - When implemented, ALL objects will use this method

Faster

Tapes are a sequential media

- Data can only be written to the end of the tape
- If there are requests to read and write a single tape
  - Fast-forward to the end of the tape
  - Write the data
  - Rewind to the location of the desired data
  - Read the data
  - This is called “shoe shining”
- Film must be read from tape while A/V are uploaded (and reverse)

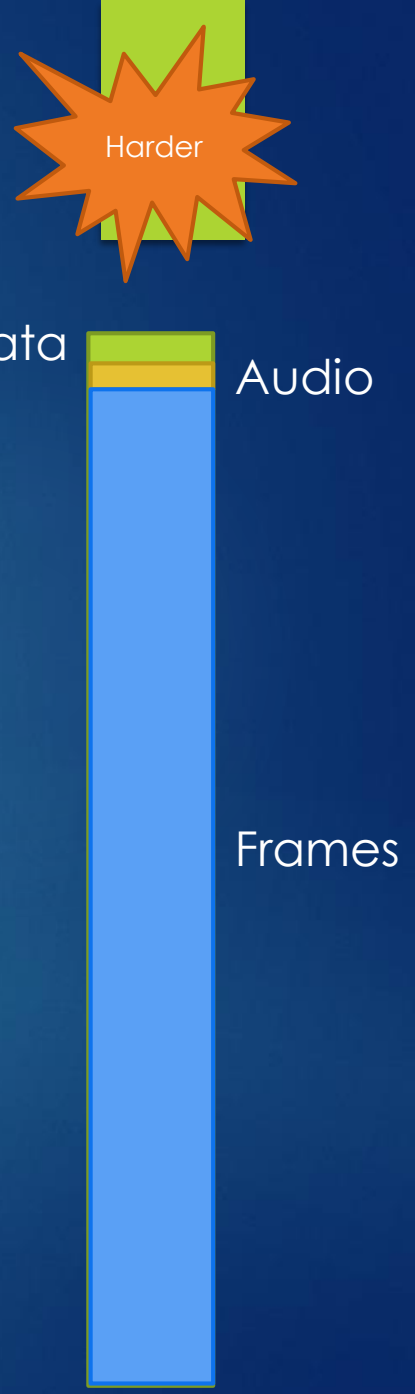
SDA uses IBM 3592 JD tapes. Each tape can store 10TB and contains 3527ft of tape

New tape pool for Film masters

- Three different tape pools
  - Film Masters
  - A/V Masters
  - Film & A/V Derivatives
- Efficiency through scheduling
  - Transcode after uploading
  - A/V & Film upload at different times
  - Distribution happens later
    - Not a real-time operation
    - At that point the tapes may be full

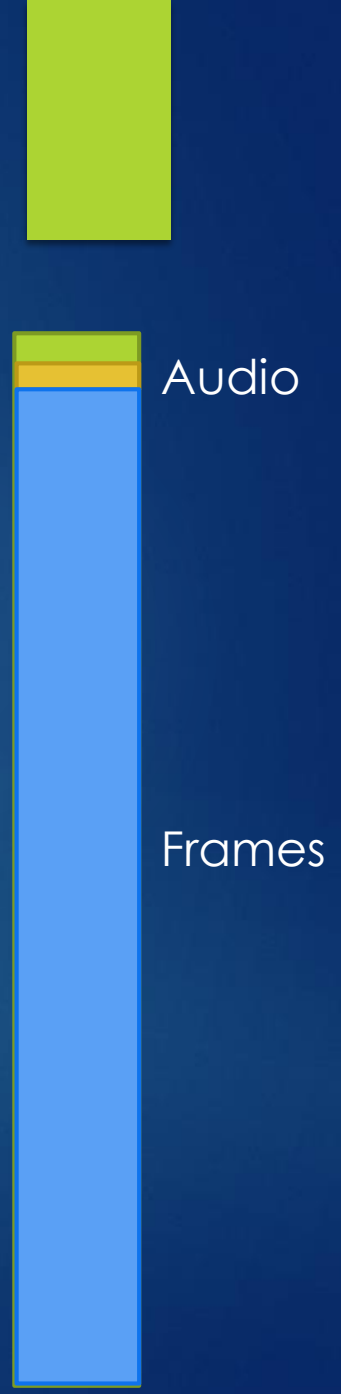
	A/V Masters	Film Masters	Derivatives
A/V upload	Write		
A/V transcode	Read		Write
Film upload		Write	
Film transcode		Read	Write
Distribute			Read

Preservation master file is simple



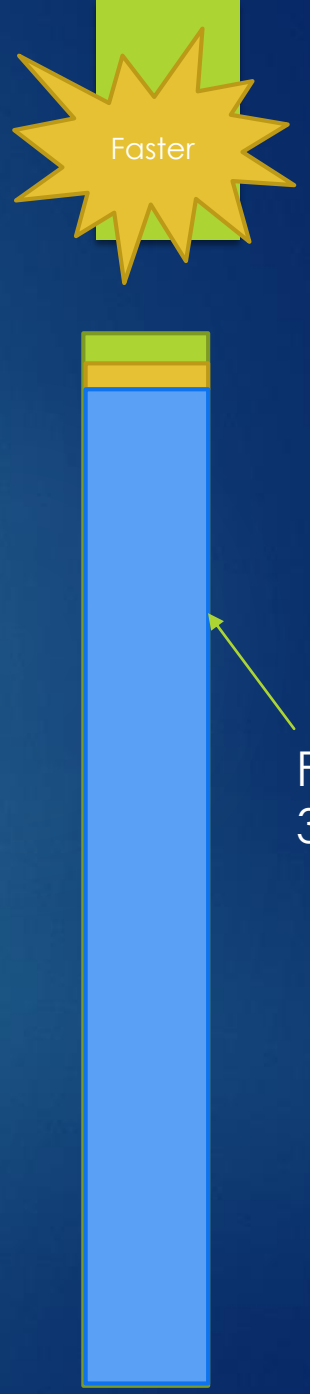
- The preservation format is a tarball consisting of:
  - A few metadata files
    - A file manifest with checksums
    - Descriptive and technical metadata
  - A WAV file for the soundtrack
    - May be absent if it is a silent film
  - A DPX image for every frame in the film
    - At 24 FPS, 1440 files per minute of film
    - Uncompressed images, ~13M per frame (2K), ~52M (4K)
  - But…

Auto QC is hard to do on tarballs



- Automated QC on a Preservation tarball needs to:
  - Verify all payload files are present and have the correct checksums
  - Make sure all DPX files have the same size
  - Spot check a percentage of the DPX files for correct metadata
  - Check the WAV file for correct structure and format
  - Check the Metadata for completeness and correctness
- The tar format makes this hard:
  - Each file consists of a header followed by data
  - The files are written sequentially
  - Finding a file means reading from the beginning until the file is found
  - Extracting the whole tarball takes longer than watching the film

Tarball index for quick retrieval



- Create an index
  - Read the tarball from end to end, reading headers, but skipping data
  - Store the header metadata and the offset/length of the data
  - Cost of reading the tarball to find a file is paid ONCE, rather than for every file extraction
  - Faster than extracting data since
    - No disk is allocated
    - Data isn't copied
- The index allows
  - Fast access to a file's data within the tarball
  - Quick file-metdata actions (i.e. checking if all files are there, size, etc.)

Multithreading automatic QC on preservation master

- Creates the tarball index
- Verify that all of the expected file names are there
- Verify the metadata files
- Verify the manifest (72 checksum threads concurrently)
  - Files aren't extracted – checksum computed in memory
- Check DPX metadata on sample set (72 frames concurrently)
  - Less than 1% are pulled, but pulled from all over the film
  - Verifies frame format, position in film, etc.
- Usual validation is 25-50% of the film's runtime

Film has many variations

Harder

- Aspects of the digitized file impact how derivatives should be made:
  - Scanning Resolution: 2K or 4K
  - Display aspect ratios: overscan & cropped
  - Pixel format: Linear or Logarithmic representation
  - Audio: Silent, Mono, or Stereo
  - Frame rate: 24, 18, other?
  - Anamorphic?
  - Warp gate used?
  - Film gauge: 8mm, 16mm, etc
- Too many combinations!

The cropped and color corrected version

An overscan frame. Perforations are on the left, the soundtrack is on the right. Portions of the previous and next frames are visible.

Parameterized configuration

- Barcode XML file parameters read by configuration code
  - Extracted directly into variables
  - Converted into other variables
- These variables are used by the automated QC

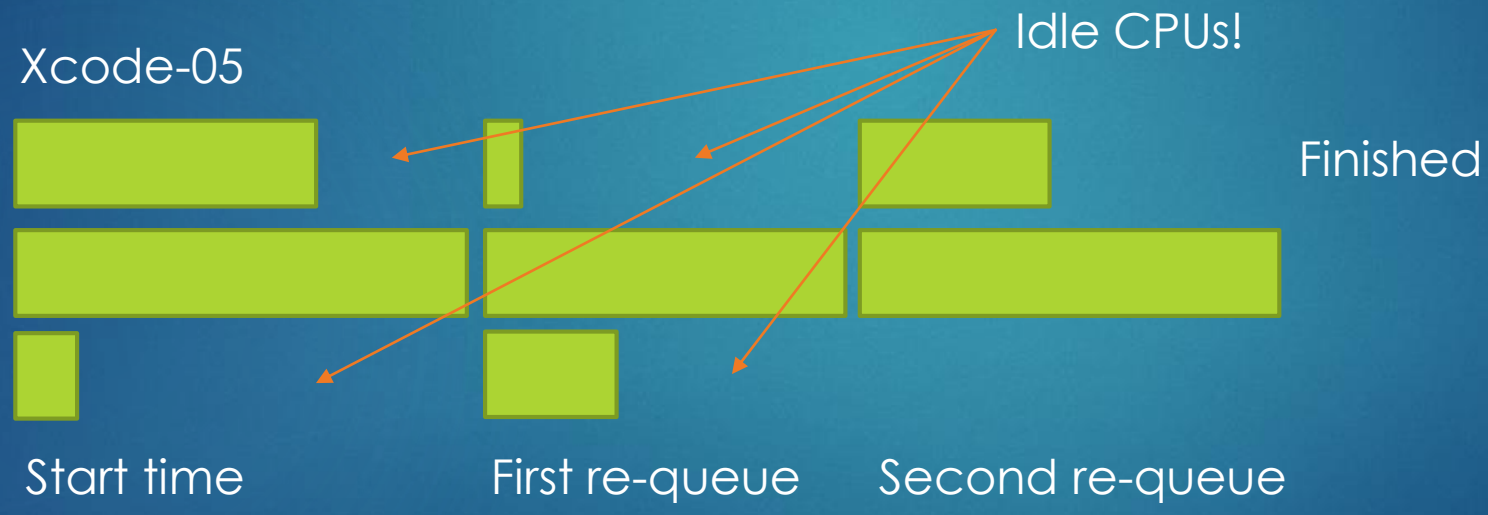
XML	QC Variable
<ScanningResolution>2k</ScanningResolution>	Width=2048
<SampleEncoding>Linear 10 bit</SampleEncoding>	DPXSampleDepth=10, DPXColorSpace=RGB
<OverscanAspectRatio>1.316:1</OverscanAspectRatio>	Height=1556

Processing time varies greatly

- Different types of objects process at different rates
  - Audio is fastest, non-VHS Video, VHS Video, Film is slowest
- The duration makes a huge difference
  - A wax cylinder is much shorter than a 2 hour DAT
  - A commercial VHS tape is 2 hours, many home-made ones are 6 hours
  - Films vary from 5 minutes to 50 minutes
- Each transcoder will load up objects until all CPUs are allocated
- Problem: Mixing short and long objects ties up the whole machine
  - Transfer times can cause the rates to vary wildly

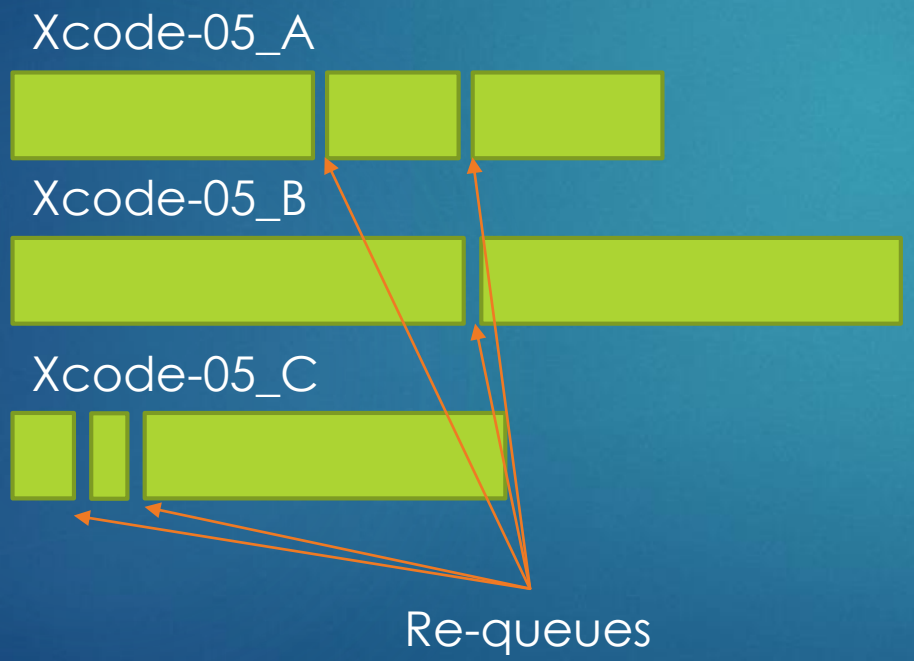
Machine queue scheduling

- Originally, each transcoding machine had a single queue that can accommodate 3 objects concurrently. It had to wait until the longest object is done before starting the next ones:



Lane-based Queues

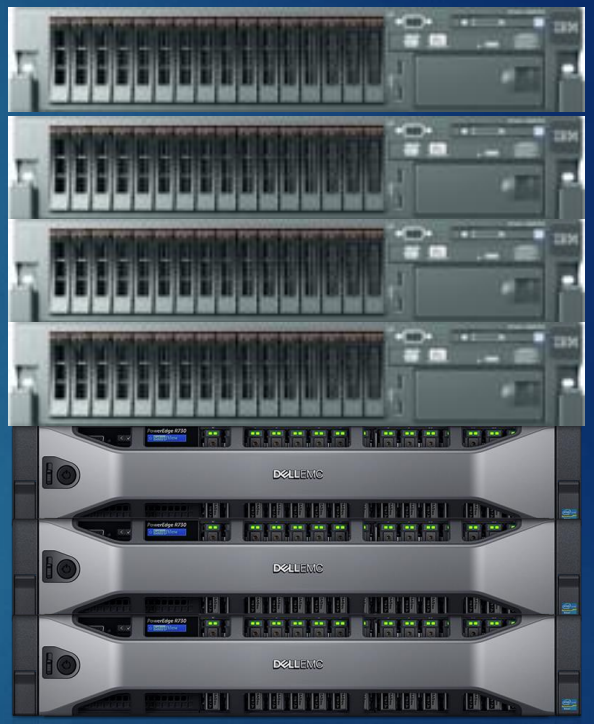
- Each machine now has multiple lanes that are queued independently



Lane-based queues have been added to all transcoders, so A/V can also take advantage of it. For VHS this has been a boon because a 6-hour tape will not clog up the system

More hardware for Film transcodes

- A/V Transcoders (4)
  - Lenovo x3650m4, 48 CPU Threads, 128G RAM, 1.5T Scratch
- Three transcoder systems were added for film
  - Dell r730, 72 CPU Threads, 256G RAM, 7.3T Scratch SSD
- Each new transcoder has 5 lanes (old ones have 3)
  - 15 film transcodes simultaneously
- New transcoders used for both Film and A/V
  - 27 queue lanes, 408 CPU Threads, 1.2T RAM, 28T Scratch



Manual QC checks

A/V

- 10% content checked
  - 1.2T per day
  - 5 days digitization weekly
  - 1 week of backlog = 6 - 10T
- Evaluation
  - Content transferred to workstation
  - Local tools used for checking

Film

- 100% content checked
  - 27T per day
  - 6 days of digitization weekly
  - 2 weeks of backlog > 324T
- Evaluation
  - Access content on file server
  - VidiCert needs to scan media
  - Local tools used for checking

Solutions for manual QC checks

Stronger

- Working/backlog space
  - 324T is unaffordable!
  - Leave out preservation master
    - Normally not needed
    - Drops from 1.5T/hour to 400G/hour (2K) or 6T/hour to 1.5T/hour (4K)
    - Greatly reduces transfer times
  - 120T disk array will provide
    - Enough space for backlog
    - Space for post-production
    - Work space for exceptional conditions
- Networking Updates
  - Enough bandwidth for mezzanines on server
- VidiCert Servers
  - Two r730 w/GPU, 64G, small SSD
  - Running Windows Server 2012r2
  - Mounts storage via Samba
- Workflow optimization
  - QC Staff pass/fail by moving folder

Current derivatives unsuitable

- Video assets in MDPI are NTSC video
  - NTSC quality is questionable, VHS even more so
  - 10 million pixels/second
- Film looks better
  - Outside of physical damage, quality can be very good
  - 75 million pixels/second (2K), 302 million pixels/second (4K)
  - Must be suitable for projection

A VHS screen shot showing
- Interlace combing
- Bottom of frame distortion
- David Byrne in a 1985 Chrysler LeBaron

Higher-quality Film derivatives

- Low quality derivative the same to allow poor network streaming
- Medium quality is the same resolution, but higher bitrate leads to better quality picture
- High quality has a higher resolution and double the bitrate.
  - 50% more pixels than video
- Table is for a 4:3 film
  - Other ratios retain height and use the computed width

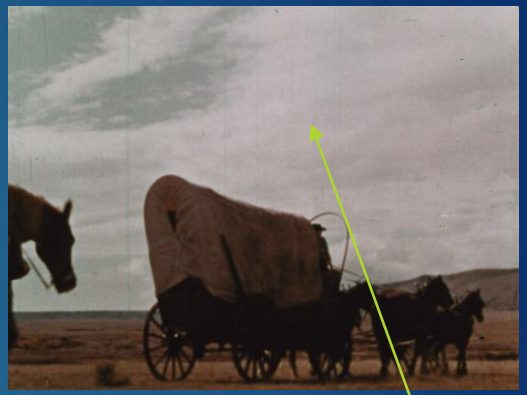
	Video	Film
Low		
Resolution	480x360	480x360
Bitrate	500Kb/s	500Kb/s
Medium		
Resolution	640x480	640x480
Bitrate	1Mb/s	2Mb/s
High		
Resolution	960x720	1200x900
Bitrate	2Mb/s	4Mb/s

Post-production activities

- Film staff need preservation file
  - Film restoration/clean up
  - Editing
  - Specific quality troubleshooting
- New born-digital content
  - From modifications above
  - New packages stored in SDA
- Automated Transcoding
  - Dropbox-based on QC server
  - Several formats available:
    - ProRes mezzanine
    - Digital Cinema Package
    - DVD Quality
- Automated SDA ingest
  - Dropbox-based on QC server

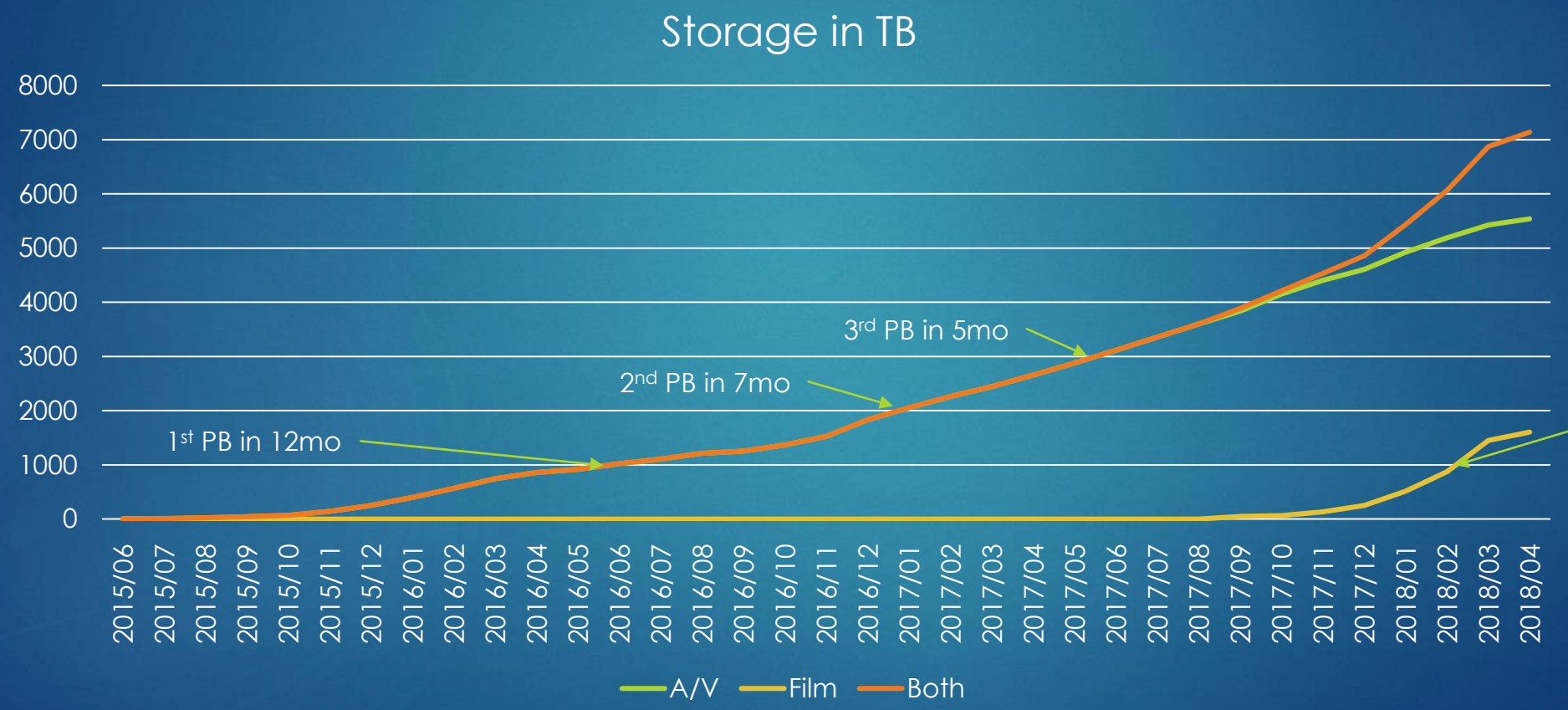
Little surprises…

- Aspect ratio precision issues
  - Given a ratio of 4:3, the height is 2048 / (4 / 3) = 1536
  - XML file specified 1.33:1, so 2048 / (1.33 / 1) = 1539
- Scanning device issues
  - Additional audio inserted into the soundtrack (7KHz noise)
  - Frame images having different shades on right/left halves
- Scanning software issues
  - Pops in soundtrack added due to audio alignment issues
  - Misc. format issues (aspect ratio metadata, DPX frame position, etc.)



Right side of this frame is slightly more green than the left. The vertical line is the boundary between the two CCDs in the scanner

Where are we now?



Since film started, we've ingested 2PB every 3 months.

If these trends continue...AAAAY!

What's next?

- A/V
  - A few new formats still coming (DVD-R)
  - Bulk digitization may wrap up by the end of the year
- Film
  - Workflow and processing improvements
  - Troubleshooting
- Both
  - SDA updates for end-to-end data integrity – throughput increase!
  - Off-site third copy of data

Thank You!

- Questions?